



INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁷ : C10J 3/54, 3/16	A1	(11) International Publication Number: WO 00/43468 (43) International Publication Date: 27 July 2000 (27.07.00)
-----------------------------------------------------------------------------------	-----------	----------------------------------------------------------------------------------------------------------------------------------

(21) International Application Number: PCT/FI00/00047
(22) International Filing Date: 24 January 2000 (24.01.00)
(30) Priority Data:
990133 25 January 1999 (25.01.99) FI
(71) Applicant (for all designated States except US): VALTION
TEKNILLINEN TUTKIMUSKESKUS [FI/FI]; Vuorim-
iehentie 5, FIN-02044 VTT (FI).
(72) Inventors; and
(75) Inventors/Applicants (for US only): KURKELA, Esa [FI/FI];
Planeetankatu 2 E 32, FIN-02210 Espoo (FI). NIEMINEN,
Matti [FI/FI]; Tammihaantie 15-17 A 1, FIN-02940 Espoo
(FI).
(74) Agent: BERGGREN OY AB; P.O. Box 16, FIN-00101
Helsinki (FI).

(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG,
BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE,
ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP,
KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA,
MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU,
SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG,
US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE,
LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM,
AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT,
BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU,
MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM,
GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published

With international search report.

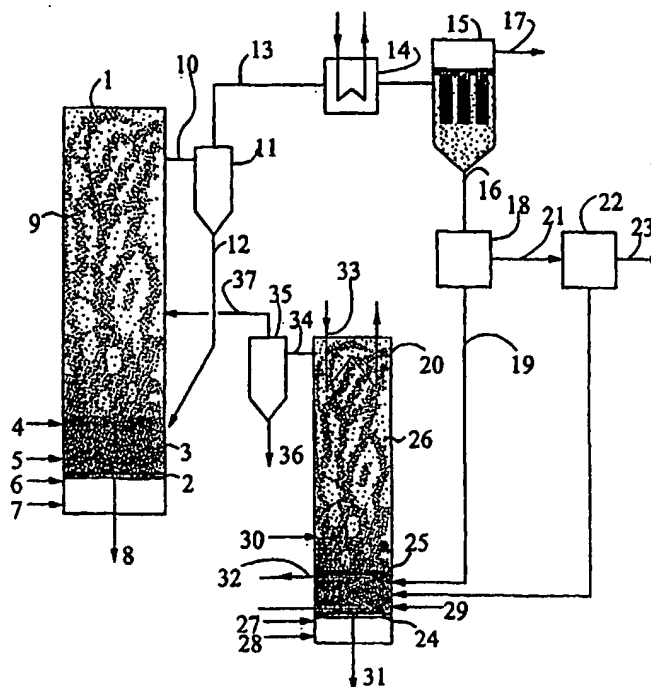
*Before the expiration of the time limit for amending the
claims and to be republished in the event of the receipt of
amendments.*

In English translation (filed in Finnish).

(54) Title: PROCESS FOR THE GASIFICATION OF CARBONACEOUS FUEL IN A FLUIDIZED BED GASIFIER

(57) Abstract

The invention relates to a process for the gasification of a carbonaceous fuel in a fluidized bed gasifier (1). In the process, a fuel (5), such as coal or peat, and a primary gasification gas (6, 7), such as air, are fed into the gasifier, and a product gas (10) is removed from the gasifier, the product gas being purified by separating fine-grained solid ingredients (16) therefrom. The solids fraction (16) which is separated from the product gas (16) and which contains unreacted carbon is fed together with a stoichiometric excess of air (27) into another fluidized bed reactor (20), which serves as an oxidizer, and the oxygen-containing gas (34) exiting from the oxidizer is directed to the fluidized bed gasifier (1) as a secondary gasification gas. By the increased oxidation, the carbon conversion in the process is increased and a residual ash with a low carbon content is produced.



FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece			TR	Turkey
BG	Bulgaria	HU	Hungary	ML	Mali	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MN	Mongolia	UA	Ukraine
BR	Brazil	IL	Israel	MR	Mauritania	UG	Uganda
BY	Belarus	IS	Iceland	MW	Malawi	US	United States of America
CA	Canada	IT	Italy	MX	Mexico	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NE	Niger	VN	Viet Nam
CG	Congo	KE	Kenya	NL	Netherlands	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NO	Norway	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	NZ	New Zealand		
CM	Cameroon			PL	Poland		
CN	China	KR	Republic of Korea	PT	Portugal		
CU	Cuba	KZ	Kazakstan	RO	Romania		
CZ	Czech Republic	LC	Saint Lucia	RU	Russian Federation		
DE	Germany	LI	Liechtenstein	SD	Sudan		
DK	Denmark	LK	Sri Lanka	SE	Sweden		
EE	Estonia	LR	Liberia	SG	Singapore		

Process for the gasification of carbonaceous fuel in a fluidized bed gasifier

- The invention relates to a process for the gasification of carbonaceous fuel in a fluidized bed gasifier, in which process fuel and a primary gasification gas are fed into the gasifier, and there is removed from the gasifier a product gas, which is purified by separating therefrom a carbonaceous solids fraction, which is further fed, together with an oxygen-containing gas, to a second fluidized bed reactor, the gas produced by this second reactor being directed to the fluidized bed gasifier as a secondary gasification gas.
- Fuels which contain large amounts of volatile components can be gasified in a fluidized bed with a high carbon conversion when the gasification temperature is sufficient, typically above 900 °C, and the solids, removed from the product gas stream by a cyclone, are recycled to the fluidized bed. On the other hand, with fuels which contain smaller amounts of volatile components and are less reactive, such as coal and peat, the carbon conversion in a corresponding simple fluidization process tends to remain below 90 %. Owing to problems of the melting and sintering of the ashes, and in air gasification also owing to the lowering of the quality of the product gas, it is in practice not possible to increase the conversion of carbon by raising the gasification temperature.
- In the known U-GAS (cf. Mason, D.M., Patel, J.G., Fuel Processing Technology, 3 (1980), pp. 181-206) and KRW processes, attempts have been made to solve the problem by creating at the bottom of the gasification reactor a high-temperature zone which is more oxidative than the rest of the fluidized bed and in which the ashes partly melt, while the surrounding bed operates at a lower temperature. Thus, a so-called agglomerating gasifier (cf. US patent publication 3,982,690) was provided, in which it is possible to withdraw selectively, from the bottom of the reactor, heavy agglomerates which contain more ashes than the rest of the bed. This process is, however, best suited for oxygen/steam gasification in which it is possible to create the required zones by the selection of the feed rates and feeding points of oxygen and steam. In air gasification, the use of water vapor is limited by the lowering of the thermal value of the gas and, furthermore, it is more difficult to create the required high-temperature zone by means of air. Also, the use of this process is limited to only fuels the ashes of which agglomerate. On the other hand, in the course of the developing of the HTW process according to FI patent publication 86075 and of the Winkler gasifier preceding it (Hebden, D., Stroud, H.J.F., Chemistry of Coal

Utilization, M.A. Elliott, ed., 2. Suppl. Vol., J. Wiley & Sons, pp. 1694-1696) it was found difficult to attain a sufficient conversion of over 95 % in the gasifier in spite of the recycling of the dusts and the high-temperature oxygen/steam gasification. Thus, it was considered better to burn in an entirely separate combustion device the dust separated by the cyclone and the filter. Many different attempts at attaining better conversion in the gasifier itself ended without results.

From US patent publication 4,828,581 there is further known the so-called Battelle Columbus process, in which two parallel fluidized bed reactors are used by circulating a hot bed material from an oxidation reactor to a gasification reactor and by keeping the product gases of the two apart. The objective is to produce without a need for oxygen a product gas with an average thermal value. This process involves the problem of the implementation of the transfer of the hot bed materials, which is difficult in particular in pressurized applications.

Another problem common in fluidized bed gasifiers, especially with sulfur-containing fuels, is that, owing to the reducing gas atmosphere, the fly ash contains compounds unstable in the environment, such as calcium sulfide, which should be oxidized before being placed in the environment.

From US patent publication 4,347,064 there is known a gasification process which uses two fluidized bed reactors, both of them serving as gasifiers. Fuel is fed into the first fluidized bed reactor, the carbon residue left ungasified therein being directed to a second fluidized bed reactor, wherein it is gasified at a higher temperature with a mixture of oxygen and water vapor. According to the publication, the proportion of oxygen in the mixture is at minimum 30 and preferably 40-70 % by volume. In addition, the publication recommends the feeding in of fresh fuel also into the said second fluidized bed reactor. The forming gasification gas is directed to the first fluidized bed reactor as fluidization gas.

The object of the invention is to provide an improved fluidized bed gasification process by which the above-mentioned carbonaceous fuels which contain smaller amounts of volatiles can be gasified with a high, above 90 %, and in preferred applications even above 95 %, carbon conversion, while the environmental problems due to the solid residue of the gasification process are decreased. It is characteristic of the process according to the invention that the said second fluidized bed reactor is used as an oxidizer by feeding into it a stoichiometric excess of air so that there occurs a complete conversion of the carbon present in the solids fraction fed in and

that a gas containing surplus oxygen is obtained, the gas being directed to the fluidized bed gasifier as gasification gas.

In the process according to the invention, the carbon left ungasified in the fluidized bed gasifier can be oxidized to carbon monoxide and/or carbon dioxide, which are
5 returned to the gasification, whereby the carbon conversion of the process is substantially increased. Alongside carbon, also other solid components which are separated from the product gas and are hazardous to the environment can be oxidized before they end up in the ash fraction to be removed from the process. The carbon content in the obtained ashes is thus low, and significant quantities of environmentally
10 toxic components are not left in the ashes.

In the fluidized bed oxidation of solids according to the invention, there may additionally occur partial agglomeration of the ashes; this facilitates the separation of ashes from the gas stream to be returned to the gasifier.

The combustion heat released in the fluidized bed oxidation according to the invention can be exploited by recovering it, the oxidizer temperature control permitting,
15 by means of a heat exchanger in a recovery of heat taking place directly from the oxidizer or from the gasifier product gas. On the other hand, the carbon dioxide and water vapor present in the secondary gasification gas produced by the oxidizer may in part be reduced in the gasifier to carbon monoxide and hydrogen, in which case
20 these for their part increase the combustion value of the product gas obtained.

According to the invention, the oxidative gas fed into the fluidized bed oxidizer is air, possibly mixed with water vapor to control the temperature in the oxidizer. The temperature prevailing in the oxidizer may be approximately 750-950 °C, preferably 800-850 °C, which suffices for rapid oxidation of the carbon present in the solids
25 and at which also the reduced compounds, such as CaS, present in the solids, are largely oxidized. From the oxidizer it is possible advantageously to recover excess heat by heat exchange in order to maintain the temperature within the said optimum range.

When necessary, a sorbent can be fed into the fluidized bed oxidizer to enhance the
30 retaining of sulfur, and also other additives, for example, to prevent the melting of the ashes. A portion of the ashes remaining after the oxidation can be withdrawn from the bottom of the fluidized bed oxidizer, and a portion can be separated by means of a separate separator, such as a cyclone, from the gas stream directed from the oxidizer to the gasifier. Owing to their higher specific weight and possibly par-

tial agglomeration, the ashes are now more easily separable than are the light ash particles, containing large amounts of porous carbon, in the product gas stream obtained from the gasifier.

Fuels suitable for gasification in the process according to the invention include coal, peat and solid biofuels such as wood. Air can be used as the primary gasification gas in the fluidized bed gasifier. The fluidized bed in the gasifier is preferably made up of a substantially stationary ebullating bed, but it is also possible to use a circulating bed reactor as the gasifier. The fluidized particles of the bed consist of a fine-grained solid material, such as sand or lime. According to the invention, the secondary gasification gas which is introduced from the fluidized bed oxidizer and which, in addition to carbon oxides and water vapor, contains oxygen left over from the oxidizing air used in excess, is most preferably fed above the ebullating bed in the gasifier. The product gas obtained from the gasifier may be directed first to a cyclone, the coarser solids fraction separated from the gas stream by the cyclone being returned to the fluidized bed of the gasifier, and thereafter, *via* a heat-recovering heat exchanger, to a filter for the separation of a finer carbonaceous solids fraction to be oxidized in accordance with the invention in a fluidized bed oxidizer.

The invention is described below in greater detail, first with reference to the accompanying drawing, which is an example of the apparatus applying the gasification process according to the invention.

The apparatus according to the drawing comprises a vertical, cylindrical reaction vessel 1 which serves as the fluidized bed gasifier and is equipped with a grate 2 in its lower section. Above the grate 2 there is a substantially stationary ebullating bed 3, which consists of fine-grained inert particles, such as sand. In the figure, the introduction of the bed material into the reaction vessel 1 is indicated by arrow 4, the feeding in of the fuel to be gasified by arrow 5, the feeding in of the gasification gas by arrows 6 and 7, for example, so that arrow 6 indicates gasification air and arrow 7 water vapor, and the withdrawal of ashes from the reaction vessel by arrow 8.

A duct 10 starting in the chamber 9 above the fluidized bed 3, at a point close to the upper end of the reaction vessel, directs the product gas formed in the gasification to a cyclone 11, which separates from the gas stream the coarser solid particles, which are returned *via* duct 12 to the fluidized bed 3 of the gasifier. From the cyclone 11 the product gas travels through duct 13 *via* a heat exchanger 14 to a particle separator 15, which is, for example, a ceramic filter. The more finely divided solids frac-

tion separated by the filter 15 exits to duct 16, and the purified product gas continues *via* duct 17 to the desired use as fuel.

Duct 16 directs the fine-grained solids separated by the separator 15 and containing a large amount of unreacted carbon first to a container 18, from which the solids are directed either *via* duct 19 directly to a fluidized bed reactor 20 serving as an oxidizer, or *via* duct 21 first to an intermediate container 22 and from there further to the fluidized bed reactor 20, in which case it is possible to remove a portion of the solids from the intermediate container (arrow 23). The fluidized bed oxidizer 20 consists of a vertical, cylindrical vessel the lower section of which is equipped with a grate 24. Above the grate 24 there is an ebullating bed 25 made up of large-sized particles of, for example, sand or lime, and a chamber 26 above the bed. The purpose of the fluidized bed oxidizer 20 is to oxidize the carbon present in the fine-grained solid material separated by the filter 15 from the product gas stream, as well as the other oxidizable components present. The feeding in of air used as the oxidative gas is indicated in the figure by arrow 27, the feeding in of optional water vapor by arrow 28, the introduction of bed material by arrow 29, possible small injection of vapor or water for the cooling of the forming combustion gas by arrow 30, and the withdrawal of ashes by arrow 31. The oxidizer 20 is also equipped with heat exchangers 32 and 33 for adjusting the oxidizing temperature to the optimal level, in which case any excess heat can be transferred for exploitation in, for example, the steam cycle of a power plant.

The gas obtained from the fluidized bed oxidizer 20, which gas, in addition to carbon oxides and water vapor, contains oxygen because of the excess of air used in the oxidation, is directed *via* duct 34 to a cyclone 35, which removes the ash particles (arrow 36) from the gas stream, which is directed *via* duct 37 to the fluidized bed gasifier 1 as a secondary gasification gas, according to the figure into the chamber 9 above the fluidized bed 3 in the reaction vessel.

In the process depicted in the drawing, a solid, particulate fuel, for example, carbon, peat, waste wood, or a mixture thereof, is pyrolyzed in the gasifier 1, forming a product gas which contains as combustible components, among other things, carbon monoxide, hydrogen and hydrocarbons. At the same time there forms residual carbon, the gasification of which is slower, and thus the particles elutriated from the gasifier along with the product gas still contain a large amount of unreacted carbonaceous material. Owing to the high carbon content, the particles are rather light in weight, and therefore only the largest particles, typically over 10-20 μm , separate from the product gas in the cyclone 11. The particles separated by the cyclone 11

and returned to the fluidized bed 3 of the gasifier react further and are finally ground to so small a size that they pass through the cyclone. In the process according to the invention, the primary cycle step made up of the cyclone 11 and duct 12 is not necessarily required at all, but the implementation of the primary cycle results in a high, approximately 80-95 %, conversion of carbon in the gasifier and thus a smaller fluidized bed oxidizer 20, which is often optimal for reasons of cost. Furthermore, it is useful in terms of the quality of the forming product gas that the upper section of the gasifier contains a large amount of carbon- and ash-containing particles, which promote the decomposition of tar compounds and the formation of the desired product gas components, carbon monoxide and hydrogen.

After the cyclone 11, the product gas travels through the heat exchanger 14, wherein the gas temperature is lowered from the typical gasification temperature (800-1000 °C) to the range of 300-550 °C. At the same time the metal vapors (e.g. alkali metals) present in the product gas condense and can be removed in connection with the removal of particles. The particles are removed, for example, with chemical filters 15, in which case the product gas 17 exiting from the process is pure and suitable, for example, for use as fuel in a gas turbine. The separated dust, which contains a large amount of carbonaceous material, can be fed directly into the fluidized bed oxidizer or, alternatively, in some run situation, all or a portion of the dust separated by the filter can be collected into an intermediate container 22 and be fed into the oxidizer later. *Via* the dust removal line 23 it is also possible to remove dust from the system, for example, in situations of disturbance or shutdown.

The conditions in the oxidizer 20 are adjusted, by control of the feeds of air, water vapor and dust, to be such that the carbonaceous material present in the dust oxidizes to carbon oxides. Since the oxidation reactions of a fine-grained carbonaceous material are considerably more rapid than the gasification reactions prevailing in the gasifier, a complete conversion of carbon will occur in the oxidizer already within the available retention time of a few seconds. Owing to the fluidized bed, the oxidizer temperature remains stable and the transfers of heat and materials are effective. The gasification process dust separated by the filter 15 contains, in addition to carbonaceous material, also other substances, such as calcium sulfide and other compounds unstable or toxic in the environment, problematic in terms of the further use or final disposal of the dust. During the oxidation, also these compounds are oxidized, and the dust to be removed by means of the cyclone 35 resembles the fly ash of a conventional combustion plant. The oxidizer temperature is adjusted to the desired level (preferably approximately 800-900 °C), either by using a large excess

- of air and/or water vapor feed, or by removing by means of an optional bed heat exchanger 32 a portion of the heat generated in the combustion, for example, for use in the steam cycle of a power plant. In the last-mentioned case, the oxidizer can be operated at a point closer to the air coefficient of stoichiometric combustion, in which case the oxygen content in the combustion gas directed to the gasifier is typically 1-5 %. The operating capacity of the cyclone 35 is based on the fact that the ash particles leaving the oxidizer 20 are clearly heavier than the porous carbonaceous particles elutriated from the gasifier 1. In addition, partial agglomeration of the ashes may occur in the oxidizer.
- 10 The hot combustion gas directed from the oxidizer 20 into the chamber 9 above the bed 3 in the gasifier serves as a secondary gasification gas; the oxygen present in it reacts rapidly with combustible compounds in the gasifier. At a high temperature, carbon dioxide and water vapor also participate in the gasification reactions occurring in the gasifier and are in part converted to carbon monoxide and hydrogen.
- 15 When the oxidizer is operated at a temperature below 850-880 °C, also alkali metals react, forming in the main condensed products (primarily alkali sulfides), which can be removed by means of the cyclone in connection with the removal of particles. When necessary, the combustion gas leaving the oxidizer can be cooled with an optional heat exchanger 33 or by slight spraying 30 of steam or water.
- 20 The fluidized beds 3, 25 of the fluidized bed reactors 1, 20 are maintained at the desired size by removing, according to need, coarse ashes 8, 31 from the bottom of the reactors and by adding, when necessary, sand, lime or some other selected bed material into the bed. By a small change of bed material, the accumulation of adhering ash agglomerates in the fluidized beds of the reactors is also avoided.
- 25 The functioning of the process according to the invention has been observed in experiments according to the following examples, in which a bituminous coal and a mixture of coal and wood were gasified in an apparatus operating under a pressure of 0.34 MPa. When corresponding fuel mixtures were gasified without an oxidation reactor according to the invention, the conversion of the elemental carbon present in
- 30 the fuel to gaseous products remained at a level of 75-90 % even though very high gasification temperatures, problematic in terms of the sintering of the ashes, were used in the experiments.

Example 1

The fuel used in the gasifier was bituminous coal alone. Approximately 55 % by weight of the carbonaceous dust separated from the hot filter was fed into the oxidizer. The bed temperature of the oxidizer was adjusted to approximately 940 °C.

5 The bed material in the oxidation reactor was a mixture of limestone and sand at a ratio of 1:1. The carbon content of the cyclone dust separated in the cyclone after the oxidizer was 0.55 % when the ashes separated by a filter and fed into the oxidizer contained carbon 65.1 %. The conversion of the filter dust fed into the oxidizer was thus almost complete. Since all of the dust was not recycled, the total

10 conversion of the coal fed in remained at 92.4 %. Even this, however, was over 10 percentage points higher than the conversion attained in conventional gasification with the same coal. During the sequence, the concentrations of vaporous alkali metals (Na, K), as well as the sulfur compounds (H₂S, COS), present in the product gas after the gasifier were measured. The total amount of vaporous alkali metals was

15 less than 0.05 ppm (wt.) and H₂S 220 ppm (vol.), and COS approximately 20 ppm (vol.). In practice this indicated that the recycling of the dust containing sulfur and alkali metals did not raise the level of impurities present in the filtered product gas as regards alkali metals or sulfur; they had been bound in the cyclone dust and been removed from the process.

20 **Example 2.**

The fuel used in the gasifier consisted of sawdust 58 % by weight and bituminous coal 42 %. All of the carbonaceous dust separated by the hot filter of the gasifier was cycled to the oxidizer (100 % recycling). The bed material in the oxidizer was the same as in Example 1, and the bed temperature was maintained at 895 °C. The

25 carbon content in the dust separated by the oxidizer cyclone was 0.25 % by weight, while the carbon content in the dust separated by the hot filter and fed into the oxidizer was 57.4 % by weight. Calculated on the basis of a gas analysis, the conversion of carbon to gases was 96 %, and on the basis of the carbon contents in the solids streams removed from the system it was over 99 %. In a corresponding conventional mixed gasification of wood and coal, a level of 82-87 % has been attained.

30 During the trial run sequence, measurements corresponding to those made during the previous experiment were made: vaporous alkali metals (Na and K in total) less than 0.05 ppm (wt.), H₂O 210 ppm (vol.), and COS 20 ppm (vol.).

Example 3

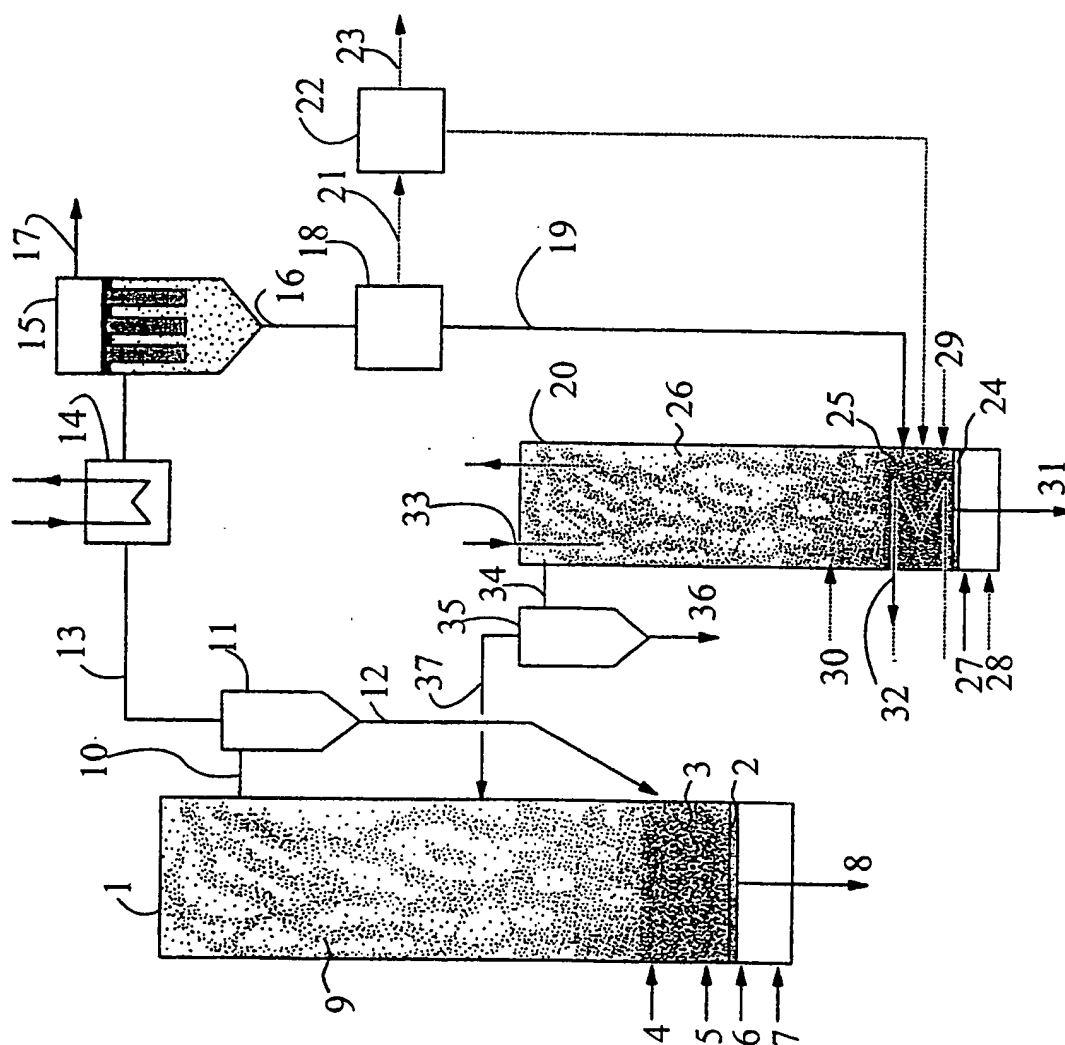
- In this experiment, the amount of hot filter dust fed into the oxidizer was more than was formed in the process during the trial sequence. Thereby a case was simulated in which dust had previously been collected in storage for later recycling. The fuel used in the gasifier consisted of sawdust 86 % by weight and bituminous coal 14 % by weight. The recycling of filter dust was 112 % by weight. The oxidizer bed material used was the same mixture of sand and limestone as in the previous examples, and the temperature of the oxidizer bed was adjusted to 850 °C. The carbon content in the dust separated by the oxidizer cyclone was 0.3 % by weight when the carbon content in the filter dust fed into the oxidizer was 34.0 % by weight. The conversion of carbon to gases, calculated on the basis of the solids streams, was over 99 %. The vaporous alkali metal contents in the gasifier product gas, measured at a point after the filter, were below 0.05 ppm (wt.), H₂S 180 ppm (vol.) and COS 20 ppm (vol.).
- No agglomeration was observed in the bottom ashes of the oxidizer during the trial runs. After the trial runs the reactor was opened and was examined to observe any sedimentation. No sedimentation was observed. The high carbon dioxide content in the gas produced was a natural consequence of the great heat losses typical of the small-scale test apparatus. In order to maintain the internal temperature balances in the reactors, a larger than conventional proportion of the fuel had to be burned. The key process variables and measured gas properties in the example experiments are shown in following Table 1.

Table 1.

Example	1	2	3
Pressure, Mpa (abs.)	0.34	0.34	0.34
Gasifier air coefficient	0.35	0.40	0.36
Total air coefficient	0.60	0.67	0.52
Carbon mass flow, g/s	4.7	2.3	1.1
Sawdust mass flow, g/s	-	2.9	6.2
Carbon/Wood ratio, % by weight	100/0	42/58	14/86
Gasifier bed material feed, g/s	0.36	0.20	0.24
Oxidizer bed material feed, g/s	0	0	0
Gasification air feed, g/s	15.3	15.2	16.1
Steam feed to gasifier, g/s	2.8	2.4	-
Air feed to oxidizer, g/s	10.7	10.5	7.6
Oxidizer fluidization velocity, m/s	0.33	0.33	0.22
Composition of dry product gas, % by vol.			
CO	8.8	6.5	8.7
CO ₂	13.3	15.4	13.9
H ₂	6.5	5.0	5.6
N ₂ (+Ar)	70.7	71.9	69.6
CH ₄	0.62	1.2	2.0
C ₂ H _y	<0.01	0.08	0.32
H ₂ S.	0.02	0.02	0.02
H ₂ O in humid gas, % by vol.	13.9	15.6	9.8
Lower thermal value of dry product gas, MJ/m ³ n	2.2	2.0	3.1
Carbon content in cyclone dust, % by weight	0.55	0.25	0.30

Claims

1. A process for the gasification of a carbonaceous fuel in a fluidized bed gasifier (1), in which process fuel (5) and a primary gasification gas (6, 7) are fed into the gasifier, and a product gas (10) is removed from the gasifier, the product gas being purified by separating therefrom a carbon-containing solids fraction (16), which is further fed, together with an oxygen-containing gas, into a second fluidized bed reactor (20), the gas produced therein being directed to the fluidized bed gasifier (1) as a secondary gasification gas, **characterized** in that the said second fluidized bed reactor (20) is used as an oxidizer by feeding into it a stoichiometric excess of air so that there occurs a complete conversion of the carbon present in the solids fraction fed in, and that a gas containing surplus oxygen is obtained, the gas being directed to the fluidized bed gasifier (1) as a gasification gas.
2. A process according to Claim 1, **characterized** in that the separation of the solids fraction (16) from the product gas is carried out by filtration (15).
3. A process according to Claim 1 or 2, **characterized** in that the temperature in the fluidized bed oxidizer (20) is approximately 800-900 °C.
4. A process according to any of the above claims, **characterized** in that a sulfur-removing sorbent is fed into the fluidized bed oxidizer (20).
5. A process according to any of the above claims, **characterized** in that a fine-grained solid material (36) is separated from the exit gas (34) of the oxidizer (20) before the gas is directed to the fluidized bed gasifier (1).
6. A process according to any of the above claims, **characterized** in that the fuel (5) is coal, peat or a solid biomass.
7. A process according to any of the above claims, **characterized** in that the primary gasification gas (6) contains air.
8. A process according to any of the above claims, **characterized** in that the fluidized bed gasifier (1) has an ebullating bed (3) made up of solid particles.
9. A process according to any of the above claims, **characterized** in that, before the separation of the solids fraction (16) to be oxidized, a coarser solids fraction (12) is separated from the product gas (10) exiting from the gasifier (1) and is returned to the gasifier.



INTERNATIONAL SEARCH REPORT

International application No.

PCT/FI 00/00047

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: C10J 3/54, C10J 3/16

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: C10J, C10B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,Y	WO 9937739 A1 (FIOTER OY), 29 July 1999 (29.07.99), page 3, line 37 - page 4, line 6; page 6, line 23 - page 7, line 8, figure 1, claim 1, abstract --	1-9
Y	US 4347064 A (LOTHAR REH ET AL), 31 August 1982 (31.08.82), column 4, line 3 - column 5, line 20, figure 1, claim 1, abstract --	1-9
A	US 3847563 A (DAVID H. ARCHER ET AL), 12 November 1974 (12.11.74), figure 1, abstract --	1-9



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

22 May 2000

Date of mailing of the international search report

29 -05- 2000

Name and mailing address of the ISA:

Swedish Patent Office
Box 5055, S-102 42 STOCKHOLM
Facsimile No. +46 8 666 02 86

Authorized officer

Marianne Bratsberg/MP
Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI 00/00047

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4026679 A (PER HARALD COLLIN), 31 May 1977 (31.05.77), figure 1, claim 1, abstract --	1-9
A	US 4444568 A (HANS BEISSWENGER ET AL), 24 April 1984 (24.04.84), figure 1, claim 1, abstract -- -----	1-9

INTERNATIONAL SEARCH REPORT

Information on patent family members

02/12/99

International application No.

PCT/FI 00/00047

Patent document cited in search report			Publication date	Patent family member(s)	Publication date
WO	9937739	A1	29/07/99	NONE	
US	4347064	A	31/08/82	AU 529097 B	26/05/83
				AU 4974279 A	21/02/80
				BR 7905303 A	13/05/80
				CS 215026 B	25/06/82
				DD 145543 A	17/12/80
				DE 2836175 A	28/02/80
				EP 0008469 A,B	05/03/80
				SE 0008469 T3	
				JP 55029593 A	01/03/80
				ZA 7903183 A	30/07/80
US	3847563	A	12/11/74	NONE	
US	4026679	A	31/05/77	AU 505758 B	29/11/79
				AU 1174676 A	15/09/77
				CA 1085167 A	09/09/80
				DE 2611191 A	07/10/76
				FR 2304661 A,B	15/10/76
				GB 1507273 A	12/04/78
				SE 387956 B,C	20/09/76
				SE 7503313 A	22/09/76
US	4444568	A	24/04/84	AR 227714 A	30/11/82
				AT 17866 T	15/02/86
				AU 545446 B	11/07/85
				AU 8238982 A	14/10/82
				BR 8201974 A	15/03/83
				CA 1179846 A	25/12/84
				CS 250214 B	16/04/87
				DE 3113993 A	11/11/82
				EP 0062363 A,B	13/10/82
				SE 0062363 T3	
				ES 511221 A	01/06/83
				FI 73724 B,C	31/07/87
				FI 821104 A	08/10/82
				GR 75461 A	20/07/84
				IE 52546 B	09/12/87
				IN 152949 A	05/05/84
				JP 1776223 C	28/07/93
				JP 4066919 B	26/10/92
				JP 57179290 A	04/11/82
				MX 159901 A	29/09/89
				NO 821072 A	08/10/82
				NZ 199930 A	31/07/85
				ZA 8202345 A	30/11/83

Form PCT/ISA/210 (patent family annex) (July 1992)